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ENVIRONMENTAL MONITORING FOR SPACE STATION WP01

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ABSTRACT. External contamination monitoring instrumentation for the Space Station work package one (WP01) elements, were imposed on the contractor as deliverable hardware. The monitoring instrumentation proposed by the WP01 contractor in response to the contract requirement includes both real time measurements and passive samples. Real time measurement instrumentation consists of quartz crystal microbalances for molecular deposition, ion gauges for vacuum pressure levels, and a mass spectrometer for gaseous species identification. Internal environmental contamination monitoring for particuulates is included in both Lab and HAB modules. Passive samples consists of four sample mounting plates mounted external to the Space Station modules, two on the U.S. LAB, and two on the HAB module.

Introduction

Space Station work package (WP01) is defined as all Space Station hardware whose development is under the responsibility of Marshall Space Flight Center (MSFC). The contractor selected by MSFC for delivering the WP01 elements is Boeing Aerospace Company (BAC). Figure 1 is taken from the WP01 contract, all of the major elements to be delivered under this contract are identified in this figure. These elements consist of the HAB module or living quarters, U.S. LAB or experimental laboratory for scientific investigations in the low gravity environment, four resource nodes for both docking and interconnnecting the various modules, and the LOG or logistics modules both pressureized (3 units) and unpressurized (2 units) for resupply of fluids, gases, and experimental instrumentation.

Requirements

Environmental monitoring requirements for the Space Station are defined in "Space Station External Contamination Control Requirements" JSC 30426. These requirements were imposed on the WP01 element contractor. Not only must the contractor provide monitoring instrumentation as part of the WP01 elements, but these elements must meet the contamination control requirements for Space Station. This means that the WP01 elements in themselves cannot be a source of contamination to a level that exceeds JSC 30426. Potential sources of contamination of the

WP01 elements include venting, thruster firings, leaks, and material offgasing. All of these sources are controlled by imposing on the WP01 contractor specific contamination control requirements. The contractor must prepare and submit a document defining how he plans to meet the requirements defined in JSC 30426 which when reviewed and approved by MSFC becomes the controlling document for the WP01 elements. This document "Contamination Control and Implementation Plan" (CCIP) D683-10126-1 has been prepared by BAC and is in the approval cycle. The CCIP covers the time period from design, through orbital operations. Materials selected must meet stringent outgasing criteria based on JSC SP-R-0022 (VCM) for vacuum compatability, and offgasing criteria based on NASA NHB 8060.1B for toxicity and flamability control. Normally all materials must meet the VCM criteria of <0.1% of the original mass at 125 °C, under hard vacuum; but in special cases when contamination sensitive optical surfaces will be directly exposed to these materials, more stringent testing is required. This more stringent testing requires that the material under question be exposed to optical witness samples identical to the flight optics, under simulated flight conditions of vacuum and temperature to verify that the optical surfaces will not be degraded by offgasing products.

Cleanliness control during fabrication must be maintained in order to deliver hardware meeting stringent surface cleanliness levels of 750 per MIL-STD-1246A for particulate and a non-volatile residue (NVR) level of <2 mg/ft^2. Hardware surfaces must be measured at various locations to verify they meet the above criteria. In addition, environmental controls along with monitoring are imposed to maintain cleanliness levels during all ground operations.

During orbital operations contamination via overboard venting is controlled by permitting only gaseous venting; and then only to the extent that the molecular column density limits in JSC 30426 are not exceeded. The other main source of contamination during orbital operations is thruster firings for station reboost and Shuttle or other vehicle docking operations. Nozzle designs for reboost thrusters are such as to minimize backflow, but still the contamination limits will probably be exceeded. These time periods during docking and reboost are designated as "nonquiescent periods" and will be unacceptable times for many experiments. After the nonquiescent periods are over the quiescent periods will be re-established for experiment observations.

Baseline Monitoring Instrumentation

Environmental monitoring instrumentation as proposed in the WP01 contract is described in Figure 2. This figure was taken directly from the Boeing contract proposal. Contamination detection instrumentation consists of the last five items at bottom of the figure. Other monitoring instruments are included in the figure and grouped together are designated as "Special Performance Instrumentation". Internal contamination environment of the modules will be monitored for particulates and molecular levels. Particulates will be measured using standard clean room type instrumentation modified for manned flight. One instrument will be located in the U.S. LAB and one in the HAB module. In addition one spare particle counter has been identified. Molecular contamination data can be obtained from the gas analyzer in the life support system (ECLS).

External contaminatin environment will be monitored to verify that the WP01 elements do not exceed their alloted contamination levels; and detect if, when, and to what extent other Space Station elements contaminate the WP01 module element radiators, windows, or other sensitive surfaces. LAB module venting from experiments or from the ECLS, including the seal leakages must be monitored and warnings issued to protect exposed sensitive experimental instruments when contamination limits are approached. Space Station reboost operations and all docking operations where thruster firings are required must also be monitored closely. If excessive contamination deposition occurs during these events, the magnitude of the contaminate deposition in terms of mg/cm^2 will be obtained with the quartz crystal microbalance (QCM) on a real time basis with sensor response times within one second.

Identification and concentration of contaminants in the gas phase in the immediate vicinity of the modules will be obtained with the mass spectrometer and ion gauge. Optical property effects on exposed surfaces to contamination will be determined from the "particle fallout" plates which are really sample plates exposing selected witness samples having surfaces sensitive to contaminatin such as thermal control coatings, window material, radiator coatings, and optical witness mirrors. These samples can be retrieved and returned to ground laboratories for detailed analysis, to determine the extent to which the actual orbital hardware surfaces have been degraded and to institute corrective actions as requried.

The instrumentation briefly described above represents the WP01 baseline contamination monitoring hardware to be delivered by the contractor (BAC). Additional monitoring instrumentation is listed in Figure 2 which will provide data for other than the contamination environment and is included to provide a better overview of the available (planned) instrumentation. It should be noted that all of this instrumentation is subject to Space Station Project review and could be reduced to meet funding limitations.

Additional Monitoring Instrumentation

One problem with the instrumentation to be provided is the lack of the real-time or inflight optical property measurements. The only direct data will be provided by the passive samples on the "partial fallout" plate which must be removed and returned to the ground laboratory for measurements. The time response for determining the level of contamination damage is at least several days. In addition the transportation environment from orbit to the ground laboratory will change the damage level on thermal control surfaces and could even effect optical mirror damage levels. Also, it is extremely difficult except in ideal situations of determining optical degradation from indirect data such as mass deposition levels. For all of the above reasons several flight instruments have been developed at MSFC to provide this missing information using real-time inflight measurements.

Data as to degradation in the vacuum ultraviolet region for specular type optics can be obtained using the "Automatic Contamination Evaluator" (ACE). This instrument was developed under the SBIR program by ARC, Inc. An operational schematic describing the functional layout is provided in Figure 3. Wavelength range is from 120 nm to 220 nm. Different wavelength ranges can be obtained by selecting different gratings, detectors, and/or light sources. A prototype flight unit has been delivered to MSFC and is undergoing operational evaluation in a space environmental simulation vacuum chamber. Optical data taken with the ACE and with standard laboratory vacuum ultraviolet reflectance and transmission instruments agree within 2%.

In the visible wavelength region two similar instruments could be utilized. One is now flying on the LDEF, and scheduled to be returned by the Shuttle late next year. This instrument is the "Thermal Control Surfaces Experiment" (TCSE), which can measure total hemispherical reflectance of coatings on a sample wheel. A schematic drawing is provided in Figure 4. An advanced version of this instrument is in the definition stage of development, under the NASA Outreach program. The advanced version is designated as the "Optical Properties Module" (OPM), and includes the additional capability to measure the total diffuse scatter of coatings throughout the visible wavelength range (220 nm to 2500 nm).

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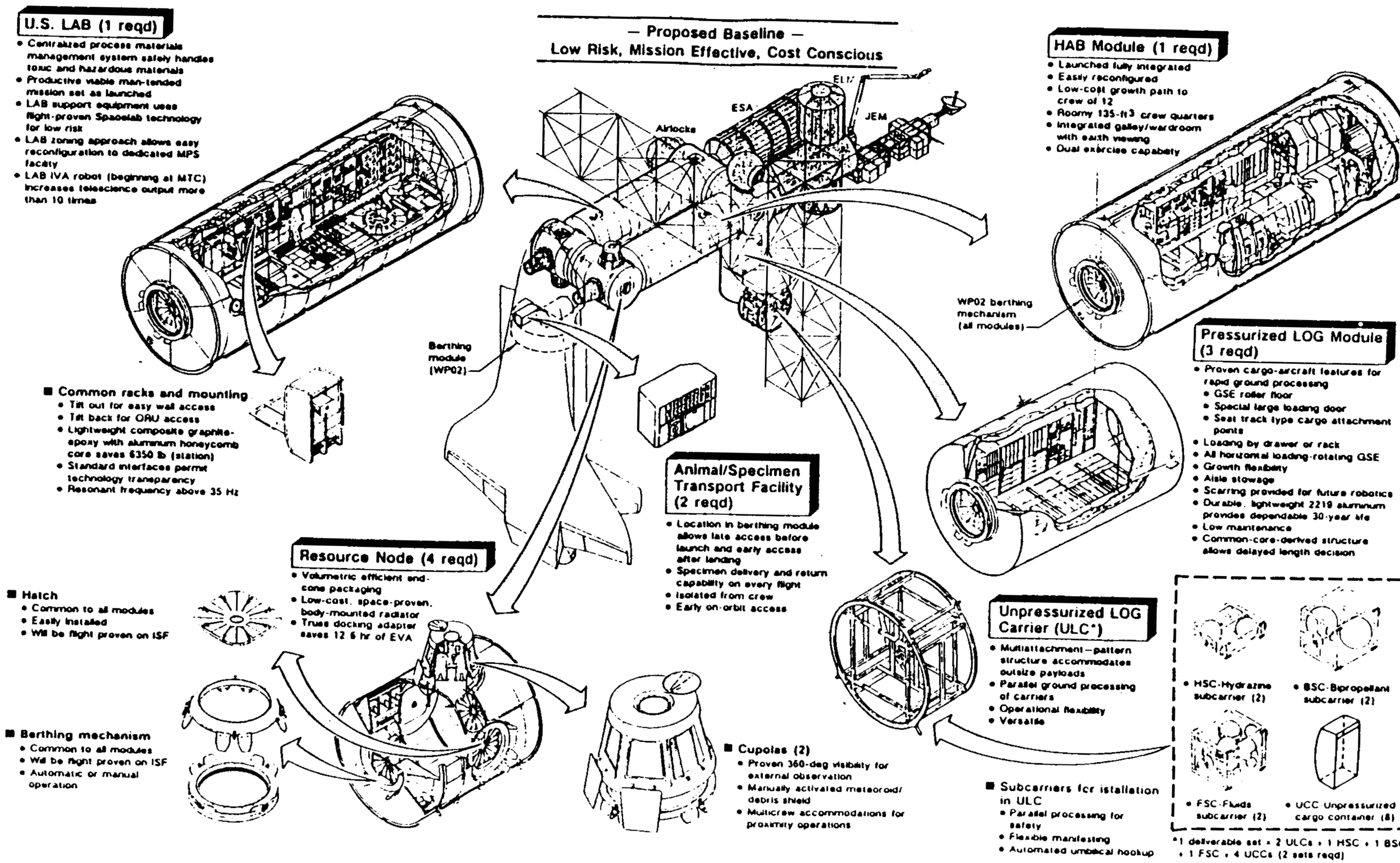

FIGURE 1

WP01 Proposed Baseline

Instrumentation description: Measurement type	Instrumentation description: Measurement method	Unit weight, lb	Unit size in³	Unit average power, W	Design maturity	Make-or-buy GFE	US LAB	HAB	Number required: Logistics Pres	Logistics Unpr	Nodes 1	Nodes 2	Nodes 3	Nodes 4	Air-lock	Spares	Location
Safety/structures																	
• Internal pressure monitor[a]	Pressure transducer	0 2	1 3	0 0	O	B	2	2	2	0	2	2	2	2	0	2	S, I, E
• Structural expansion monitor	Strain gauge	0 1	0 1	0 0	O	B	10	10	10	10	5	5	5	5	0	2	I/E
• Thermographic monitor	Thermographic scanner	3 8	329 9	0 2	N	B	1	1	0	0	0	0	0	0	0	0	E
• Internal acoustics monitor[b]	Piezoelectric crystal	1 9	90 2	0 0	M	B	1	1	1	0	0	0	0	0	0	1	I
• Pressure shell acoustics monitor	Piezoelectric crystal	0 2	1 2	0 0	M	B	4	4	4	0	4	4	4	4	0	2	I
	Preamplifier	0 3	18 9	2 0	M	B	4	4	4	0	4	4	4	4	0	2	I
• Rack latch position indicator	Switch	0 1	0 1	0 0	O	B	44	44	12	0	0	0	0	0	0	2	I
• External mechanism connection indicator[c]	Switch	0 1	0 1	0 0	O	B	2	2	2	4	8	8	8	8	2	2	E
Radiation detection and Monitoring																	
• Structural current monitor[d]	Current probe	0 2	1 2	0 0	M	B	10	10	5	5	2	2	2	2	2	1	I/E
• Ionizing radiation detector	Scintillation counter	1 2	300 5	5 0	O	B	2	2	1	1	1	1	1	1	0	1	I
• Static charge monitor	Voltage probe	1 1	4 9	0 3	M	B	8	8	4	4	4	4	4	4	0	2	I/E
• Power transient monitor[e]	Current probe	0 9	1 2	0 0	N	B	4	4	1	0	0	0	0	0	0	1	I
• Plazma detection monitor	Ionization detecter	15 2	300 5	23 1	N	B	1	1	0	0	0	0	0	0	0	1	E
• Electric field monitor	Antenna	1 1	4 9	0 0	M	B	3	2	1	1	1	1	1	1	0	1	I
Trend/verification																	
• Incipient failure device monitor[f]	Piezoelectric crystal	0 1	1 2	0 0	M	B	10	10	2	0	2	2	2	2	2	2	I
	Preamplifier	0 3	1 2	2 0	M	B	10	10	2	0	2	2	2	2	2	2	I
Contamination detection																	
• Particle fallout	Sample plates	0 3	9 0	0 0	N	B	2	2	0	0	0	0	0	0	0	1	E
• Particle environment	Particle counter	54 4	875 0	8 3	M	B	1	1	0	0	0	0	0	0	0	0	I
• Molecular deposition	Quartz crystal microbalance	3 0	11 0	1 5	O	B	2	2	0	0	0	0	0	0	0	0	E
• Pressure	Ion gauge	0 5	137 6	1 8	M	B	2	2	0	0	0	0	0	0	0	1	E
• Species[g]	Mass spectrometer	52 6	925 0	9 0	M	B	0	1	0	0	0	0	0	0	0	0	E
						Weight, lb	115 7	167 2	16 4	9 2	11 9	11 9	11 9	11 9	1 4	26 4	
						Volume, ft³	1 6	2 1	0 3	2	0 2	0 2	0 2	0 2	0 1	0 5	
						Avg power, W	78 5	87 5	18 2	87 5	18 2	18 2	18 2	18 2	4 0	0 0	

Legend:
S Shell
I Internal
E External

a Redundant device
b Portable unit, rechargeable battery
c Indicates positive connection (umbilicals, berthing, hatches)
d Measures circulating current in structure
e One per PDCU, power (EPS, WP04)
f Criticality 1 rotating devices
g ECLS LAB mass spectrometer will be used in LAB

All signal conditioning will be in sensor or MDM, preamplifier/signal conditioner power supplied by MDM

FIGURE 2 *Special Performance Instrumentation*

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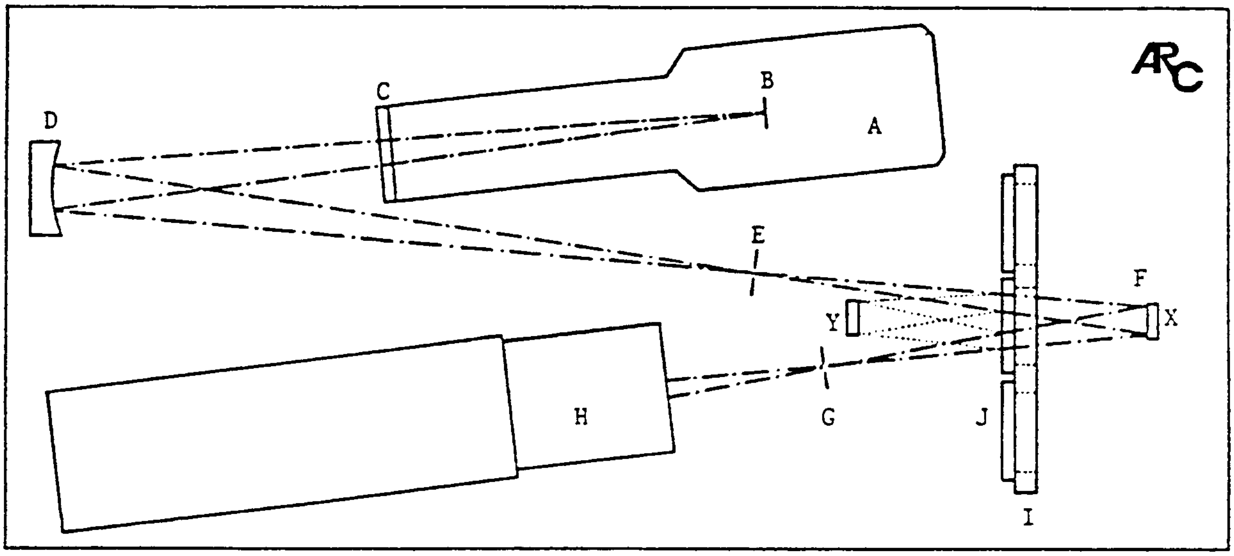
ACE OPTICAL SYSTEM



A. Light Source

B. 1mm Diameter Entrance Aperture

C. MgF2 Window

D. Holographic Grating, 1800 g/mm, 200mm concave radius

E. 1mm Exit Aperture

F. Indexable Concave "Mode Mirror"

G. Light Baffle

H. Solar Blind Detector

I. Sample Wheel

J. Sample

X. 100% Baseline, and Transmittance Measurement Position

Y. Reflectance Measurement Position

FIGURE 3

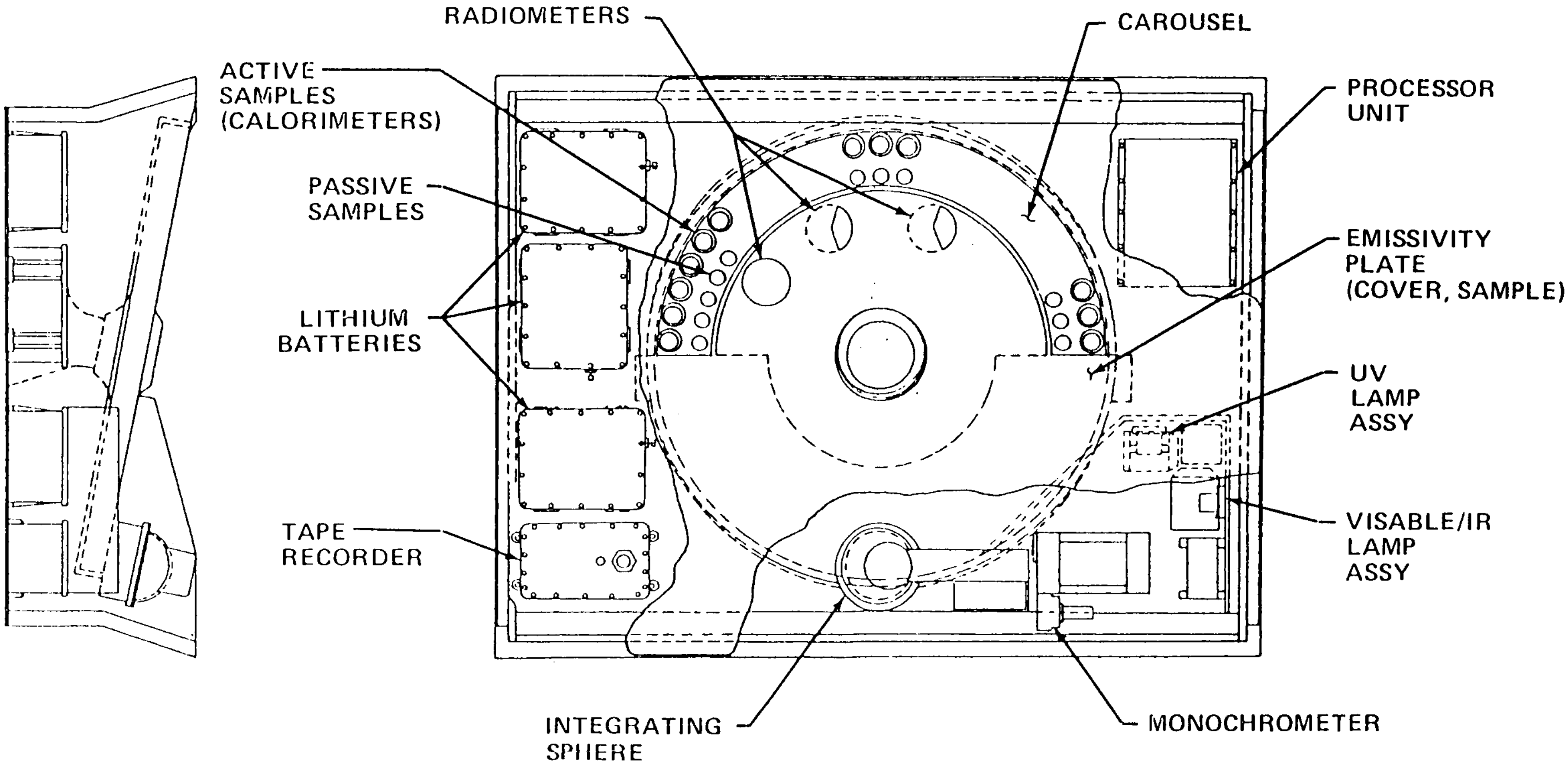


FIGURE 4 – Thermal Control Surfaces Experiment Assembly